ESTO

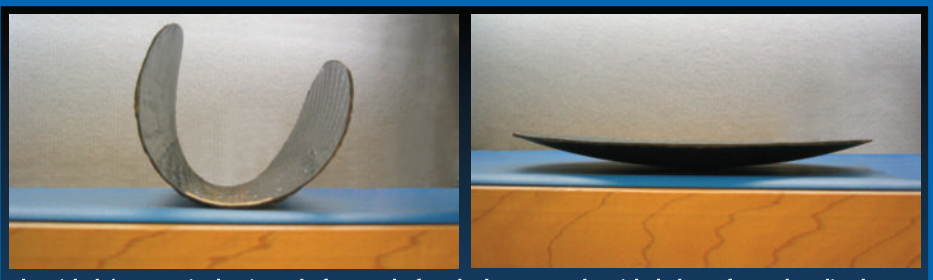
Earth-Sun System Technology Office

SHAPE MEMORY COMPOSITE MATERIALS FOR LIGHTWEIGHT, DEPLOYABLE OPTICS

Large, lightweight, deployable antennas will be a critical component in realizing a number of future science measurement objectives. This project demonstrates the applicability of new shape memory materials that can be stowed compactly for launch, and later deployed to a stiff and stable structure suitable for a wide range of applications.

How It Works

The shape memory materials used in the production of these optics are similar to traditional carbon fiber-reinforced composites except that they include a shape memory polymer resin based on cyanate ester. The unique properties of this resin allow the optics to be put under high packaging strain without damage. The strain is induced by heating the material, flexing it mechanically, and then cooling it to "freeze" the strained material in a shape suitable for packaging. Deployment, or shape recovery, is achieved by re-heating the composite material, which releases its strain to return to its "normal," pre-packaged shape.



The nickel / composite laminate before and after deployment. The nickel electroformed replica layer provides a smooth, accurate optical surface. The shape memory polymer layer is carbon fiber-reinforced for light weight and controlled deployment.

A key challenge was the application of a reflective, optically accurate surface to the composite. Low-stress nickel was electroformed using an existing convex stainless steel mirror as a master template. The back surface of the nickel was then plasma etched and adhered to the composite material. Testing has shown the resulting laminate of nickel with the shape memory composite to be very robust – so much so that the composite material fails before the nickel delaminates.

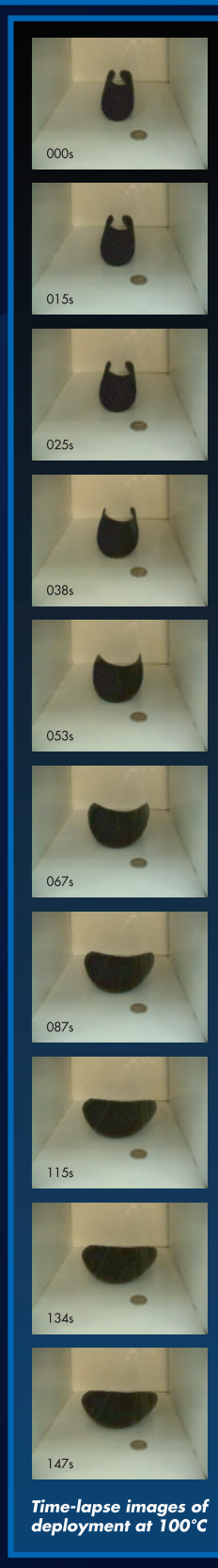
A 1 meter deployable reflector of shape memory composite was manufactured and tested through repeated stow and deployment cycles, demonstrating surface repeatability to +/- 0.5 mm.

Features

- Lightweight, compact, and deployable - less than 5 kg per square meter-packing enabled by resin deformations of 10-40%, reducing mission cost and enabling higher orbits.
- Enables larger apertures that can enhance instrument capabilities
- Manufacturing process that relies on a master optic makes reproduction fast and inexpensive
- Combines high optical surface accuracy with a stiff monolithic structure
- Eliminates the need for complex deployment mechanisms
- Can be stowed and deployed in a configuration that protects optical surfaces from abrasion or damage

Future Applications

- Enables improved measurements of precipitation and soil moisture, which require apertures in the range of 4 meters and larger
- May vastly enhance measurement accuracy of sea ice, snow cover, snow water equivalent, ocean salinity, and ocean surface winds



Time-lapse images of deployment at 100°C

Acknowledgments

Team Members:
Steven Varlese, Ball Aerospace & Technologies Corp.; Melville Ulmer, Northwestern University; Jason Hermiller, Cornerstone Research Group (CRG)

Funding:
Earth-Sun System Technology Office (ESTO) as an Advanced Component Technologies (ACT) project as well as supplemental funding by Ball Aerospace and CRG internal research funds and a NASA Space Grant

www.esto.nasa.gov

NASA